On the application of disinfectants in arresting the spread of the cattle plague : report to Her Majesty's commissioners / by William Crookes.

ON THE

APPLICATION OF DISINFECTANTS

IN

ARRESTING THE SPREAD

OF THE

CATTLE PLAGUE.

Report to Her Majesty's Commissioners.

BY

WILLIAM CROOKES, F.R.S.

(Reprinted from the Appendix to the Third Report of the Cattle Plague Commission.)

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Disinfection in connection with the Cattle Plague.

(Extracted from the Third Report of the Cattle Plague Commissioners.)

"Disinfection, in the sense in which the word is used here, implies the destruction of an animal poison, in whatever way it is accomplished. To find a perfect disinfectant for the Cattle Plague poison would be to stop the disease at once. We have naturally been very desirous of discovering a substance with such a power; but much more evidence is necessary before we can venture to affirm that success has been obtained. In the first instance we requested Dr. Angus Smith to undertake this subject, with a view of seeing what chemical agent would be best suited for the purpose. Subsequently, at his suggestion, Mr. Crookes was asked to carry on various practical trials which might test the efficacy of two agents which Dr. Angus Smith had reported to us as likely to be useful. We refer to the reports of these two gentlemen for an explanation of the present doctrines of infection, and an enumeration of the different substances which may be used to destroy the poison. On examining these different agents it is soon found that the number of those which can be employed with advantage is limited. Since the poison is constantly given off in discharges flowing from diseased surfaces, and since it may be suspended like

impalpable dust in the air, it becomes necessary that any disinfectant should act continuously both on the discharges and on the air. No disinfectant can be efficacious if its action is intermittent, or if it does not act on both sources of danger. It is evident, indeed, that the poison ought to be destroyed at the very moment of evolution or discharge. Every minute during which it remains active increases the danger. The disinfectant must, therefore, not only be both fixed and volatile, but so cheap and easily used as to be continually in action, and it must of course be innocuous to cattle and men. A large number of substances which can be used in many other cases as disinfectants must be put aside, as not meeting these necessary conditions. Compounds of iron, zinc, lead, manganese, arsenic, sodium, lime, or charcoal powder, and many other substances, want the volatile disinfecting power; iodine, bromine, nitrous acid, and some other bodies are too dear, or are entirely volatile, or are injurious to the cattle. On full consideration, it appears that the choice must lie between chlorine, ozone, sulphur, and the tar acids (carbolic and cresylic). Two of these bodies, viz., chlorine, in the shape of chloride of lime, and the tar acids, have the great advantage of being both liquid and aëriform; they can be at once added to discharges, and constantly diffused in the air. All these four substances—chlorine, ozone, sulphurous acid, and the tar acids—have been practically tested, either in England or on the Continent, and there is considerable evidence that they all actually do destroy the Cattle Plague poison. Their precise mode of action is still uncertain. Chlorine and ozone act, no doubt, as powerful oxidisers, converting animal poisons into simple and innocuous substances. Sulphurous acid probably destroys the virus by its strong antiseptic powers. The tar acids, according to the experiments of Mr. Crookes, neither

interrupt nor accelerate oxidation, but they act most powerfully in arresting all kinds of fermentative and putrefactive changes, and annihilate with the greatest certainty all the lower forms of life. After a full consideration of the relative merits of the four disinfectants, and after some practical trials, Mr. Crookes arrived at the conclusion that the most powerful, and at the same time most simple, process of disinfection would be to use the tar acids as constant liquid and aëriform disinfectants, and sulphur in the form of sulphurous acid as an additional and occasional agency. In our First Report we recommended both these agents in a state of combination; the best mode of using them in a free state will be found detailed in Mr. Crookes's report, and in the instructions which we furnished to your Majesty's Government in February last, and which will be found in the Appendix. The general result of experiments on disinfection with carbolic acid and sulphur is certainly very encouraging. For the details of these experiments, which have been careful and searching, we refer to Mr. Crookes's report. It is, of course, most desirable that no false hopes should be raised, for we have seen but too many instances in which a rude disappointment has utterly crushed what seemed reasonable expectations. But no one can peruse the account of what has been done without seeing that a fair case has been made out for a large and systematic trial of these measures. They must, however, be fairly tried; they must be used with perseverance and energy; not grudgingly or insufficiently, as has sometimes been the case, but with the determination to keep the disinfectant in presence of the poison everywhere and constantly, so that every particle of virus may be, without fail, subjected to its action. For the reasons stated in Mr. Crookes's report, it appears that chloride of lime is inferior to the combined use of carbolic

and sulphurous acids. But there is no doubt of the efficacy of this agent, and in certain circumstances, as for the washing of railway trucks, it may be employed in addition to boiling water or steam. It is very desirable that the use of carbolic acid should become general throughout the country in uninfected as well as in infected districts. There is little doubt that even were there no danger from Cattle Plague, the great purifying effect of this substance on the air of cattle sheds would contribute greatly to the health of the animals."

ON THE

APPLICATION OF DISINFECTANTS

IN

Arresting the Spread of the Cattle Plague.

Report to Her Majesty's Commissioners, by WILLIAM CROOKES, F.R.S.

PART I.

THEORETICAL CONSIDERATIONS AS TO THE PROPAGATION OF THE CATTLE PLAGUE.

1. Previous to my receiving instructions from the Royal Commission for inquiring into the origin and nature of the cattle plague, I had devoted considerable attention to the investigation of the applicability of disinfectants to the prevention or cure of this pestilence, ever since its first appearance in England, and had tried numerous experiments both in the laboratory and also on a large scale in farmyards. I was therefore not unprepared to commence at once the practical operations which it was considered desirable to carry out.

2. As to the bare fact of the infectious* nature of the cattle plague all are agreed. That contamination of some kind is communicated from a diseased to a healthy animal is obvious to every one; but when we inquire by what agency the disease is carried, the answers are of the most conflicting kind. Something, evidently a material substance, passes from one beast

* I have throughout this Report used the word "infectious" in preference to "contagious." The limitation to actual contact involved in the word *contagious*, and the popular opinions which the use of these words foster, that some diseases are infectious and not contagious, whilst others may be contagious though not infectious, imply a far more profound knowledge of the way in which diseases are transmitted than we yet possess. I therefore prefer the wider term infectious, as being more applicable to our present knowledge on the subject.

to another; but what is this something? Is it a solid, a liquid, or a gas; living or dead; an animal or a vegetable germ; a poison, virus or ferment? Each of these views has found advocates, and in favour of each something may be said.

3. There are weighty reasons for deciding that the infecting matter is neither a gas nor even a volatile liquid. The almost infinite attenuation which a gas undergoes owing to its rapid diffusion into the atmosphere, would render its supposed noxious influence imperceptible a few yards from the focus of infection. Moreover, the infection is capable of being carried considerable distances in clothing or running water, and in a variety of ways incompatible with the behaviour of gases. For these reasons, and many others unnecessary to adduce here, it seems clear that the disease must be communicated by the agency of solid, non-volatile particles.

4. The specific disease-producing particles must, moreover, be organised, and possess vitality; they must partake of the nature of *virus* rather than of *poison*.* No poison yet known to chemists can approach, even in a faint degree, the tremendous energy of the active agent of infectious diseases. A poison may be organic, but it is not organised. It may kill with far greater rapidity than the virus of infection, but, unlike this virus, it cannot multiply itself in the animal economy to such an extent as to endow within a few hours every portion of its juices with the power of producing similar results. A virus, on the contrary, renders the liquids of an infected animal as virulent as the original germ. Strychnine may be regarded as the type of a poison, and vaccine matter as the type of a virus.

5. Many considerations tend to show that the virus of cattle plague is a body similar to vaccine lymph, and consists of germinal matter, or living cells, possessing physiological individuality, which, if not exposed to extremes of heat, cold, or dryness, are capable of preserving their activity for a certain time

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* The words *virus* and *poison* are generally regarded as synonymous. It would be more convenient, and would tend to promote accuracy of thought, were the distinction here made generally adopted.

outside the living organism, of adhering to material objects, and of being carried from one place to another by currents of air; each, when introduced into the blood, requires a certain time (known as the period of incubation) during which the septic germs develope and multiply, until they have so far poisoned the blood that the ordinary symptoms of disease become manifest.

The blood poisoning thus set up may legitimately be called "fermentation;" it is a decomposition caused by the act of nutrition of the living cell, whereby it reproduces in incalculable numbers the specific septic germs which have given it birth. These gradually infest the blood and other animal liquids, and as the disease progresses are discharged from the skin, throat, glands, &c.; the breath, perspiration, and excreta of the animals forming vehicles for the distribution of the virus. By "living" cells, is not meant living, in the sense in which an animal, or even a low form of infusoria, lives; but living as a seed, or as vaccine matter, even when dried, may be living, inasmuch as it still possesses reproductive vitality.

6. It is by no means certain that the multiplication of these individual cells is the immediate cause of the blood poisoning. The analogy of the action of virus on the blood, to that of yeast on sugar, renders it more probable that this is not the fact. In the case of the best-known ferment—yeast—its cells multiply by feeding upon the sugar in the liquid; alcohol and carbonic acid being their excretions. It is therefore probable that during the multiplication of the virus cells, they, in a similar manner, impoverish and weaken the blood, by feeding upon some element in it, whilst at the same time they excrete a poison to which the symptoms of the disease may be immediately due.

7. The foregoing view differs from the prevalent notion that the virus of contagion consists of decomposing organic matter, declining from a complex towards a more simple chemical constitution, and during its degradation inducing decomposition in the neighbouring particles of matter. This chemical theory at first sight appears very plausible; but it fails to satisfy one necessary condition of the present

case. It is possible to imagine that the force set free in the declension of a complex chemical molecule to a more simple form will be sufficient to raise a neighbouring molecule to a structure almost as complicated as the original; but according to this view the ferment would be constantly diminishing, whereas in reality it constantly increases in bulk. The hypothesis is therefore insufficient to explain the prodigious procreative power of the original particle. This power belongs only to the nature of an organised germ, capable of producing multiples of itself by a process of nutrition and subdivision. Thus the line of demarcation between organic poison and organised virus appears to be very clearly defined.

This necessarily brief outline of the theoretical views which have governed me in the present investigation will, it is hoped, be clearer and more intelligible after perusing the experimental proofs which follow. They have been corroborated by numerous small laboratory experiments, as well as by practical operations at different farmhouses.

8. Whether this theory thus briefly sketched be adopted or not, or whether it be regarded as a provisional scientific artifice, it certainly includes and explains a far greater number of the phenomena of pestilence than any other hitherto propounded. Moreover, it is the theory sanctioned by the most influential of those medical philosophers who have the best right to be heard on this subject, and notably by the distinguished Registrar-General, Dr. Farr, who by the adoption of the word zymotic, in his classification of diseases, has implied his adhesion to this theory.

9. Bearing upon the communicability of this disease are other questions, which hitherto have not received a satisfactory settlement. How does the virus travel? What amount of resistance to ordinary conditions of moisture and time does its vitality confer upon it? Will it propagate and multiply, outside the animal body, under favourable conditions of warmth and moisture? And can we find any chemical disinfectant or antiseptic which will readily destroy it?

The extreme communicability of the pestilence may arise either from the eminently diffusible character of the virus-cells, or from their persistent vitality, or

from both conditions combined. It is proved that the *materies morbi* will adhere to clothing, and can be carried a considerable distance in it; that the breath, perspiration, and evacuations of the diseased animal are loaded with virus-cells; and that the secretions from the mouth, nose, and eyes are in a similar condition. It follows, therefore, that the sheds, in which diseased animals have stood, become impregnated with the virus, ready to settle on the clothes of every one who enters; that ponds, streams, and even wells may become contaminated through foul soakage; that a road over which diseased cattle have been driven may be poisoned along its whole distance by the evacuations and other discharges from the animals; whilst their very breath, carried by the wind, may plant the seeds of infection in all the healthy farms by which the road passes.

There is no difficulty in admitting that the infection may travel for a certain limited distance through the air, and it is even likely that it may be carried longer distances by fogs, or heavy vapours, or by the gases of putrid decomposition; but it appears in the highest degree improbable that the germs should be able to retain their vitality for any length of time in the atmosphere.

10. Sufficient data do not at present exist to decide whether the germs can propagate themselves apart from the animal. Viewing them as of the nature of a ferment, it is not impossible that they may live and multiply in other warm liquids besides the blood; but the most reasonable supposition seems to be that the presence of decaying organic matter, or the gaseous emanations from putrefying dunghills, preserves, or may even revive, the expiring vitality of germs brought by men, dogs, birds, vermin, or perhaps the wind; whilst the same causes which foster the virus-cells,—dirt, overcrowding, constant re-breathing of their own and the adjacent animals' breath, an insufficient supply of fresh air, the presence of ammonia and other gases of putrefaction, together with inappropriate food,—may establish a deteriorated state of body, which causes the animals to fall ready victims at the first approach of the plague.

The existence of these unfavourable conditions may

account for the fact that on some farms the disease assumes a character so virulent that no remedy or preservative is of any avail against it, every head of cattle being swept off one after another, each attack being fatal within three days (15, 79, 80). In the words of a writer in the "Edinburgh Review," "a single spark of infected matter accidentally thrown into the animal economy, thus reduced, as it were, to a touchwood state, fires the mass, which burns until it is consumed."

PART II.

ON DISINFECTANTS GENERALLY.

11. There appears as yet but faint hope of finding a cure for the disease, and even were medical science to supply that great boon, it would be of little use unless supplemented with vigorous disinfecting measures; otherwise it would be like attempting to put out a fire fed on all sides with inflammable materials. Disinfection must, therefore, be the first consideration, and should be carried as far as possible short of endangering the health of the sound animals by the agents employed. Disinfectants and antiseptics have necessarily a powerful action on vital phenomena; and in some cases it may happen that an animal's vital powers are so diminished by the disease that it will not have strength left to bear the remedial treatment; but even in this case less harm will be done by its use than if the animal had been allowed to die of cattle plague.

12. Disinfection, in the widest sense of the term, includes deodorisation, and means the neutralisation or destruction of all substances, arising from putrefying organic matter, or emanating from diseased animals, either injurious to health or offensive to the sense of smell.

The putrefactive products of animal and vegetable matter are found to consist of some or all of the following gases and vapours:—

Sulphuretted hydrogen,
Phosphuretted hydrogen,
Ammonia,

Phosphorus- and nitrogen-bases of complex constitution,
Acetic, butyric, valerianic, &c., acids,
Carburetted hydrogen,
Hydrogen,
Carbonic oxide,
Carbonic acid,
Nitrogen,
Various organised animal and vegetable products of little or no activity, and
The special virus of infection. (The latter in an infected district.)

13. In a more restricted sense, the term "disinfectants" is used to express those agents which destroy organic or offensive matter by oxidation or analogous action; whilst under the term "antiseptics" are classed those agents which prevent chemical change by destroying the tendency to putrefy. The latter are termed, by Dr. Angus Smith, colytics, from κωλύω, I arrest.

14. Oxidising disinfectants are by far the best known and most popular, inasmuch as they appeal directly to popular prejudice, by destroying the foul odours which are the usual accompaniments of infection, whilst antiseptics have little or no action on these gases. I hope to succeed in showing that this fallacious mode of estimating the relative value of disinfectants and antiseptics, is one which does great injustice to the latter.

15. Cleanliness, ventilation, and good drainage have been spoken of as comprising all that is required to preserve cattle from the plague. This is not correct. Due attention to these points will certainly tend to preserve the animals in better health, and will render them more fitted to sustain the exhausting action of the disease; but ventilation, cleanliness, and drainage are unavailing against the importation of the germs of disease from adjacent herds. These measures are of value as they remove what might otherwise become nurseries for infection. A germ from without, falling on to a clean dry stall, is likely soon to die; but if it meet with moisture and dirt, its vitality may be fostered, and the chance of its coming in contact with a healthy animal so much the more increased (10).

Cleanliness, drainage, and ventilation are admirable adjuncts to disinfection, but it is not safe to trust to them alone to ward off the plague. Ventilation, by allowing a greater number of cubic feet of air per minute to pass over the animals, may be, in fact, the means of conveying the infection to them. A moderately ventilated shed, in which antiseptics are freely employed, has been proved to be a place far safer for cattle than an open field; although when the animals have caught the disease the mortality appears to be less when they are turned out into an open field than when they are kept in sheds.

16. Dr. Angus Smith, by his exhaustive examination of disinfectants, has rendered it unnecessary for me to search amongst the numerous class of possibly useful bodies for those likely to be of practical value. His results I accept in the full conviction that they are correct; and I proceed to investigate the respective merits of the comparatively small number of agents available for disinfection.

17. At the outset it is necessary to strike off at once a whole class of valuable agents which will not meet the requirements of the case. It appears to have been satisfactorily proved that the infectious matter passes off mainly from the lungs of diseased animals, and that it attacks healthy ones through the same channels. It is suspended in the air with fogs, vapour, and gaseous products of decomposition, settling on rafters and in crevices whence mechanical purification would be unlikely to dislodge it. Partaking in this manner of the physical properties of a vapour, or of fine dust, it is clearly hopeless to attempt to combat the virus by non-volatile solid or liquid disinfectants.

18. For this reason charcoal, chloride of zinc (Sir William Burnett's disinfecting fluid), solutions of metallic salts, and other similar substances are of very limited use. Moreover, chloride of zinc (and this is probably true of the other metallic chlorides) has been proved to possess no efficacy in destroying specific infective emanations. What is wanted is a volatile and liquid disinfectant, which after first acting on the excreta, the floors, walls, and stalls of the shed, will, by its quality of gaseous diffusion, rise into the air, enter the

lungs of the animals, pervade the whole building, and attack the hidden germs of infection, which otherwise would escape. In addition to this the agent must do its work with as little inconvenience as possible to the cattle and their attendants.

19. Some disinfectants, however suitable in other respects, are too expensive, unsafe, or injurious to health, to be used: such are bromine, iodine, peroxide of hydrogen, hypo-nitric acid, and hypo-nitrous acid.

20. The value of excessive heat as a disinfectant is very great, but it is available only in a limited number of cases. It acts in two ways. Heat, to the boiling point of water, continued for half an hour or more, acts as an antiseptic, perfectly destroying the vitality of all germs of contagion, or virus cells. In this way clothing and similar substances are conveniently disinfected. Heat, pushed to destruction in the presence of air, acts as a disinfectant, by promoting oxidation. The disinfecting value of the combustion of infected substances is too well known to require further notice.

21. Hydrochloric acid gas (evolved from salt and oil of vitriol) is most irritating to the respiratory organs, and is very inferior in its action to either sulphurous acid or chlorine. Besides, when evolved in white-washed sheds, it unites with the lime on the walls, forming a highly deliquescent compound, chloride of calcium, which keeps them permanently damp. The employment of a dangerously corrosive body like oil of vitriol should also be avoided.

22. Oil of tar can also be removed from the list, its value entirely depending upon the small amount of the tar acids it contains (34). To the same class petroleum belongs. This body has been used with considerable success in Wallachia by M. Etienne R. Veron, who, in an interesting pamphlet, which he has taken great pains to draw up, and forward to this country (in the hope that it may prove as useful here as it has been on his estate), has given full details of the means he employed to extinguish (*étouffer*) the disease, and then keep it from his farms, in 1864.

Every animal which showed the least signs of disease was at once killed. He then caused all parts of the sheds, which could have been in contact with the

animals, to be washed with petroleum, and the bodies of the cattle were afterwards rubbed over with a cloth soaked in the same material. The farm servants had orders to wash their hands, boots, &c., in a mixture of petroleum and water, and to sprinkle their clothes with the mixture, whilst a little petroleum was added to the animals' food and drink. Their excrements were frequently removed, and the floor was sprinkled with petroleum. No dogs were admitted on any pretence.

For five days these precautions were rigidly observed, when they were somewhat relaxed. They were attended with complete success, and there is little doubt that, carried out as rigidly in this country, the same good results would ensue. A copy of M. Veron's pamphlet was forwarded to me, and many experiments have been made in consequence. Petroleum depends for its value upon a small quantity (1 or 2 per cent.) of either carbolic acid or a substance allied to it, and Dr. Angus Smith has shown that when this substance is removed by appropriate means the purified petroleum has no antiseptic value. This being the case, no experiments on the large scale were tried with petroleum, as they would necessarily be similar, but inferior in their results, to those of the tar acids.

23. The choice is therefore limited to the oxidising disinfectants—chlorine and ozone, and the antiseptics —sulphurous and the tar acids. These are representative bodies, and numerous trials have been made with them before coming to a conclusion as to their respective merits; the results being embodied in the following pages.

24. I am bound to admit that the conclusion to which I have been forced to come is quite opposed to my preconceived ideas on the subject. I started with a strong bias in favour of chlorine and ozone, but the irresistible force of the arguments derived from my experiments has caused me to alter my opinion.

Oxidising Disinfectants.

25. At first sight nothing appears more perfect than the action of a powerfully oxidising disinfectant, like chlorine or ozone, upon noxious vapours and septic

germs. In presence of an excess of either of these agents, all organic impurity is at once burnt up, and reduced to its simplest combinations; and could we always rely upon the presence of a sufficient amount of either of these bodies, no other purifier would be needed. But in practical work on a farm these disinfectants are always very inadequate, except perhaps for half an hour or so during the day; at other times, the oxidizing agent has presented to it far more noxious material than it can by possibility conquer, and being governed in its combinations by definite laws of chemical affinity, the sulphuretted and carburetted hydrogen, the nitrogen- and phosphorus-bases, &c., would all have to be burnt up before the oxidizing agent could touch the germs of infection; whilst the continued renewal of the gases of putrefaction would be perpetually shielding the infectious matter from destruction.

It is here that the great objection lies to disinfectants which act by oxidation. If we arrange in a series, (as set forth in par. 12), the possible substances which may be met with in an infected shed, and gradually mix with them chlorine or ozonized air, we find that those vapours having strong and fœtid odours, and which stand at the commencement of the list, are the first to go; whilst the actual virus of the disease—the organized particles which have no odour whatever—are the last to be attacked. But in using disinfectants of this class, the only test of efficiency which a workman would employ, is the sense of smell, and I have on several occasions known it happen that a deodorized shed, to all outward appearances disinfected, was still in reality saturated with infection. It so happens that the stinking gases of decomposition are of little or no danger in the atmosphere, whilst the deadly virus-cells of infectious diseases are inappreciable to the sense of smell. Mere deodorization is therefore no protection whatever.

The following experiment tends to illustrate, if not to prove this:—Cheese mites were put into water mixed with strongly smelling cheese and sulphuretted hydrogen. Aqueous solution of chlorine was gradually dropped into the mixture from a burette. The smell of sulphuretted hydrogen was the first to go,

then some smell of cheese, but it required a considerable quantity of chlorine to kill the mites. Exactly the same experiment was now repeated, only leaving out the sulphuretted hydrogen and cheese. The chlorine now had nothing to divert its energy from the cheese mites, which were consequently killed before one-fourth the quantity of chlorine used in the first instance had been added.

Again, oxidizing disinfectants possess little if any continuous action. What they attack is destroyed perfectly, but what they leave has no special resistance to decomposition conferred upon it. They remove the products of decomposition, but they do not take away the power of further putrefaction.

In addition to these general faults possessed by oxidizing disinfectants, the following special objections may be urged against chlorine and ozone:—

26. **Chlorine.**—This agent requires to be liberated in the gaseous state by a chemical process. This at the outset is an objection, for experience shows that farm labourers are not fit persons to be trusted with the performance of a chemical experiment involving the use of corrosive acids. The smell of chlorine is very irritating to the lungs of diseased or convalescent animals; and instances have come to my knowledge in which permanent injury has resulted from its employment. Moreover, the cattle dislike it much. Its action is more energetic upon the valuable constituents of the manure than upon septic germs*: it rapidly attacks ammoniacal compounds, the urea and hippuric acid, and considerably reduces the manurial value of farm-yard stuff. If much ammonia is present in the shed, chloride of nitrogen is likely to be formed, the vapour of which, even in minute quantities, is painfully distressing to the eyes of cattle and of their attendants. Another great objection is that gaseous chlorine, being absorbed by the whitewash, soon forms chloride of calcium (21. 28.), the deliquescence

* I find it recorded in the *Medical Record* for March 15, 1866, that Dr. J. P. Loines, of New York, as the result of a series of experiments, has come to the conclusion that chlorine, in quantity sufficient to be irrespirable, has no effect upon the infecting property of the vaccine crust; and, reasoning from this analogy, he is of opinion that the same is the case with the virus of variola.

of which will make the walls of the building permanently damp, and fitted to foster the vitality of virus-cells, should they fall upon them.

27. A plan of fumigation by chlorine has recently been recommended which appears to possess another disadvantage. It is based upon the decomposition of chlorate of potash by hydrochloric acid. This reaction does not evolve pure chlorine, but a gas called euchlorine (supposed to be a mixture of chlorine and chloric oxide). The properties of this gas are different from those of chlorine, and nothing is known about its special value as a disinfectant. It is dangerously explosive, the act of transferring it from one vessel to another, or even the warmth of the hand, being sometimes sufficient to shatter the vessel to pieces with a loud report.

28. If commercial chloride of lime is used as the source of chlorine, there is the additional disadvantage that the compound into which it changes—chloride of calcium—is, as before mentioned (21. 26.), very deliquescent, and will leave the floors, walls, and especially the woodwork washed with it, permanently damp; whilst, if thrown in the solid state on the floor, it rapidly attracts moisture, and becomes unpleasantly wet. It also communicates a disagreeable odour to the hands when it is touched. It is one of the things most easily adulterated, and it would be scarcely possible to supply an ordinary consumer with a test by which he could ascertain its strength and purity.

29. **Ozone**.—This powerful agent attacks all kinds of organic matter with intense energy. But as in the case of chlorine, the specific substance which we most want to destroy would be nearly the last to go; and, as it would be almost impossible to generate ozone in quantity in an infected shed, its energies would in most cases be spent in doing useless work. When much ozone is present in the air it acts hurtfully on the respiratory organs.

Owing to the extremely poisonous nature of phosphorus, and its ready inflammability, danger would arise from the production of ozone by the slow combustion of this element. In the hands of ordinary farm servants serious accidents from fire would be constantly occurring.

Antiseptics.

30. Oxidizing disinfectants produce their effect by actually destroying infecting substances. Antiseptics act simply by destroying their activity. The former act more energetically upon dead than living organic matter. Antiseptics attack first the opposite end of the scale, and destroy vitality; they exert little or no action on the foul-smelling and comparatively harmless gases of decomposition, but they act with intense energy on the inodorous germs of infection which these gases may carry into the atmosphere along with them.

If, therefore, the theory with which I started be correct; if the matter which conveys infection from one animal to another be of the nature of an organized germ; if it owe its tremendous powers of destruction to the presence in it of vitality,—then antiseptics are the only agents fitted to deal with this special case; for they leave almost untouched the crowd of simply odorous gases, and seek out and destroy the one thing to be feared. When I treat of carbolic acid, ample proof of the correctness of this view will be given.

31. **Sulphur Fumigation.**—Of all disinfecting processes, this is, perhaps, the oldest. Its action was well known in the days of Homer, for we read that Ulysses employed it to remove the smell of dead bodies.* It is recorded by Ovid† that the shepherds of Italy yearly purified their flocks and herds with burning sulphur,

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* Hom. Od., xxii., 481.

Ulysses. Οἶσε θέειον, γρηῦ, κακῶν ἄκος, οἶσε δέ μοι πῦρ,
Ὄφρα θεειώσω μέγαρον . . . .
493. Ἤνεγκεν δ' ἄρα πῦρ καὶ θήϊον· αὐτὰρ Ὀδυσσεὺς
Εὖ διεθείωσεν μέγαρον καὶ δῶμα καὶ αὐλήν.

O old woman, bring brimstone, the relief of evils, and bring me fire, in order that I may fumigate with brimstone the house. . . . .

And then she brought fire and brimstone, and Ulysses well fumigated with brimstone the house, and the court, and the hall.

† Ovid, Fast., iv., 735, &c.

Pastor, oves saturas ad prima crepuscula lustra
Uda prius spargat, virgaque verrat humum.
Frondibus, et fixis decorentur ovilia ramis;
Et tegat ornatas longa corona fores.
Cærulei fiant vivo de sulfure fumi;
Tactaque fumanti sulfure balet ovis.

and passages in other writers show that they averted disease from them by this means.

Professor Graham, Master of the Mint, says, that of gaseous disinfectants "sulphurous acid gas (obtained by burning sulphur) is preferable, on theoretical grounds, to chlorine. No agent checks so effectually the first development of animal and vegetable life. All animal odours and emanations are immediately and most effectually destroyed by it."

The value of sulphurous acid in arresting the progress of the cattle plague, has been proved beyond a doubt by the experiments of Dr. Dewar, and my own results entirely confirm his. When, however, used by itself, it can be employed only very sparingly in sheds, when cattle are in them; it is very stifling, and its powerful deoxidising action would retard the conversion of the peroxide of iron into protoxide by the act of respiration—a result equivalent to that produced by breathing an atmosphere containing less than its normal amount of oxygen, which has been shown by Dr. Angus Smith* to be incompatible with health. For this reason I prefer to use it only as an additional precaution, relying principally upon other agents. Sulphurous acid acts in many cases through its affinity for oxygen, but it possesses also great antiseptic powers of its own, so that a slight exposure to it is sufficient to destroy the vitality of germs. The following experiment proves this :—

A mixture of sugar syrup and yeast was kept in a warm room until it became in a state of active fermentation. An aqueous solution of sulphurous acid was added, when the fermentation instantly ceased. When examined under the microscope after treatment with sulphurous acid, no apparent change was observed in the appearance of the yeast cells.

32. When sulphurous acid is produced in a whitewashed shed, it unites with the lime on the walls,

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O shepherd purify the fruitful sheep at the earliest dawn: let the moist bough first sprinkle and sweep the ground. Let the sheepfolds be decorated with foliage and boughs fixed, and let a lengthy wreath ornament the doors. Let there be blue smoke of burning sulphur, and let the sheep bleat at being touched with the sulphur.

* "Report on the Air of Mines," by R. Angus Smith, Ph.D., F.R.S., being part of the Appendix to the Report of the Royal Mines Commission, London, 1864.

forming non-deliquescent sulphite of lime, one of the valuable ingredients in McDougall's disinfecting powder; its good effect therefore does not cease as soon as the atmosphere is free from its odour.

The gaseous acid has a great affinity for water; the natural moisture always present in clothing, or on the woodwork and other parts of cowsheds most likely to retain infection, is able to absorb the gas in quantity sufficient to form a solution in contact with which virus-cells cannot exist. When absorbed in this manner it is only very slowly evolved,—a fact which has been noticed by all who have been in sheds whilst undergoing this mode of purification,—the fumes of the burning sulphur being said to "hang about" the clothes for a considerable time. Articles of clothing, boots, tools, sacks, cloths, baskets, pails, ropes, and any other portable article which may require disinfection, are conveniently purified by allowing them to remain in a close shed whilst it is undergoing sulphur fumigation.

Sulphurous acid, in addition to its antiseptic qualities, is a deodoriser of considerable energy. It destroys the powerful odour of most of the offensive gases named in paragraph 12. It attacks and oxidises sulphuretted hydrogen, entirely destroying it; it neutralises the strong smell of ammonia and other alkaline bases, converting them into sulphites, but without destroying their manurial value or losing its antiseptic properties. In this respect it differs in an important manner from chlorine.

The use of sulphurous acid is open to one or two objections. When absorbed on clothing or damp woodwork, it gradually oxidises into sulphuric acid. In cowsheds this is not of much consequence, as there is always sufficient ammonia present to neutralize it; but if repeatedly formed on clothing, it will bleach the articles, and ultimately make them rotten. When neutralized with lime or ammonia, or other bases, the antiseptic value of the sulphurous acid is not impaired, but it is tied down to one spot, and prevented from acting in the atmosphere. When the sulphites thus formed are allowed to remain in contact with wet organic matter, they gradually decompose with evolution of sulphuretted hydrogen; but this decomposition

is stopped at once by an additional fumigation with sulphur, and if the sheds are cleaned out every day it will never occur. Sulphites have been used with success by Professor Polli and Dr. De Ricci, both as prophylactics and as curative agents, in diseases caused by blood poisoning: in Dr. De Ricci's words, they neutralize the zymotic principle—the ferment—without being injurious to life.

33. **The Tar Acids (carbolic and cresylic acids).**—These two bodies are so commonly known under the name of acids, that I shall continue so to designate them, although by chemists they are more generally classed with the alcohols. They have great similarity, and only within the last few months have they been met with separately in commerce, having hitherto been both called carbolic acid. Creosote, (κρέας σώζειν, to preserve flesh), prepared from coal tar, one of the most powerful antiseptics known, was thought to be impure carbolic acid, until 1854, when Professor Williamson and Mr. Fairlie, in an investigation of it, discovered that it was a mixture of carbolic and cresylic acids. It was then taken for granted that Reichenbach's creosote, from wood tar, had a similar composition, until Hlasiwetz, in 1858, showed that this creosote was a different body from carbolic or cresylic acids. Finally Dr. Hugo Müller, in 1864, discovered that true creosote, and its analogue guaiacol, belonged to a different class of bodies, and consisted of methyl-oxy-phenic and methyl-oxy-cresylic acids. No experiments on the large scale have yet been tried with true creosote, as I have only been aware within the last few weeks that this compound could be obtained in quantity.

Pure carbolic acid is a white crystalline solid, melting at 34° C., and distilling at 180° C.; a trace of water or oily impurity renders it liquid, and for disinfecting purposes it is always supplied in this form, to avoid the extra expense and trouble needed for the separation of the last traces of impurity; cresylic acid is liquid, it boils at 203° C., and closely resembles carbolic acid in odour and other properties. Before the commencement of these inquiries it was thought to be of little or no value as a disinfectant, but Dr. Angus Smith has lately shown that it rivals, if it does not surpass, carbolic acid in antiseptic pro-

perties. For the present purpose of cattle plague disinfection it is immaterial which acid is used, and to avoid unnecessary repetition I shall use the term carbolic acid to express either acid, or the commercial mixture of the two acids.

34. From time immemorial carbolic acid, creosote, or bodies containing them, have been used as antiseptics. Passages in Pliny, read by the light of chemical science, show that the Egyptians used for embalming their mummies a compound made from pitch, which must have contained large quantities of creosote. Carbolic acid is the active agent in tar, which, either in its ordinary state or burnt as a fumigator, has always held high rank amongst disinfectants. Pitch and tar were the most popular medicines in use against the cattle plague when it visited this island in the last century; the animals being preserved against contagion by having their noses and jaws rubbed with tar, whilst the cowhouses were disinfected by burning pitch and tar in them (in which process a certain quantity of the vapours of carbolic acid would escape combustion). The almost universal custom of burning gum resins and odoriferous woods in connexion with religious ceremonies may have originally arisen from the disinfecting powers of the creosote in the smoke. The well-known efficacy of smoke in preserving meat is entirely due to the presence in it of this agent.

Pitch oil, oil of tar, and similar products owe their value entirely to carbolic acid (22). This body may in fact be called the active principle of tar, just as quinine is the active principle of bark, or morphia of opium, and it has the great advantage of being easily prepared in any country where coal or wood can be obtained.

35. Sulphurous acid probably owes some of its antiseptic value to its affinity for oxygen, whereby the oxidation of the matter under treatment is retarded. It has been suggested that the value of carbolic acid is due to a similar property, and that it acts merely by preventing oxidation. It being important to a thorough understanding of its action that this point should be settled, the following experiments were made:—

I. Lumps of metallic sodium were cut with a sharp

knife: the progress of the oxidation could be readily followed by the change of colour of the surface. The experiment was tried several times in an atmosphere strongly charged with the vapour of pure carbolic acid and of cresylic acid; comparative experiments being made at the same time in pure air. No difference in the rate or amount of oxidation could be detected.

II. A colourless solution of subchloride of copper in ammonia was prepared and divided into two parts; one being mixed with a little carbolic acid. On pouring them through the air into flat white dishes, no difference in the progress of the oxidation could be detected.

III. A mixture of pyrogallic acid and solution of potash was shaken up in a large stoppered bottle. It was then opened under water, and the amount of absorption of the atmospheric oxygen noted. The same experiment was repeated after the addition of carbolic acid to the potash solution. The same quantities were used, and the agitation was continued for the same time. On again opening the bottle under water the absorption was found to be the same as before.

IV. The last experiment was repeated, substituting crystals of sulphate of iron for pyrogallic acid. The result showed equally that the presence of carbolic acid exerted no retarding influence on the oxidation.

V. Iron filings were shaken up in water with the same result.

VI. A "philosophical lamp" was made by arranging a platinum spiral over the wick of a spirit lamp, containing alcohol mixed with a little ether; on lighting, and then blowing it out, the platinum continued to glow brightly. Pieces of solid carbolic acid were then carefully placed in the cup of the brass wick holder, surrounding, but not in contact with, the wick. The heat soon melted the acid and raised its vapour round the platinum spiral, but without occasioning any alteration in the brightness of its glow.

VII. Lead pyrophorus was poured into two long and narrow jars of air, one of which had its interior moistened with liquid carbolic acid. Not the slightest appreciable difference could be detected between the rapidity of oxidation in the two jars.

VIII. Paper moistened with sulphate of manganese solution, and dried, was dipped into caustic ammonia, both with and without carbolic acid. No difference whatever could be detected in the rate of its darkening.

These experiments prove conclusively that the tar acids have no special power of retarding oxidation.

36. Other experiments were then instituted in the endeavour to understand more clearly the mode of action of carbolic acid.

IX. Some meat was hung up in the air till the odour of putrefaction was strong. It was then divided into two pieces; one was soaked for half an hour in chloride of lime solution, and was then washed and hung up again; the offensive smell had entirely gone. The other piece of meat was soaked in a solution of carbolic acid containing 1 per cent. of the acid; it was then dried and hung up. The surface of the meat was whitened, its offensive odour was not removed, though it was masked by the carbolic acid. In two days' time the bad odour had quite gone, and was replaced by a pure but faint smell of carbolic acid. In a few weeks' time the pieces of meat were examined again. The one which had been deodorized with chloride of lime now smelt as offensively as it did at first, whilst the piece treated with carbolic acid had simply dried up, and had no offensive odour whatever. It was then hung up for another month and examined; no change had taken place.

X. A piece of fresh meat was soaked in a one-per-cent. aqueous solution of carbolic acid for one hour; it was then wrapped in paper and hung up in a sitting-room in which there was a fire almost daily; at the end of ten weeks it was examined. It had dried up to about one-fourth of its original size, but looked and smelt perfectly good and fresh, a very faint odour of carbolic acid being all that was perceptible. It was soaked for twenty-four hours in water, and then stewed with appropriate condiments and eaten; it was perfectly sweet, and scarcely distinguishable from fresh meat, except by possessing a very faint flavour of carbolic acid, not strong enough to be unpleasant.

XI. Animal membranes in the forms of gut, skin,

and bladder, were perfectly preserved if immersed direct in aqueous solution containing 1 per cent. of carbolic acid; but if previously moistened with water, and then immersed in dilute carbolic acid, the preservation of the skins was not so complete.

XII. Animal size and glue, mixed, in the form of solution, with small quantities of carbolic acid, were perfectly preserved from change even in hot weather.

These are important experiments. They point out in a striking manner the difference between mere deodorizers and antiseptics. Hitherto attention has been almost entirely confined to the deodorization of gases arising from putrescence. The effect has been combated, whilst the removal of the cause has received scarcely any attention. Chloride of lime, one of the strongest of the class of deodorizers, acts, as has been shown, only on the gases of existing putrefaction, but it has no influence over the future. Carbolic acid, on the other hand, has scarcely any action on fœtid gases; but it attacks the cause which produces them, and, at the same time, puts the organic matter in such a state that it never re-acquires its tendency to putrefy.

37. It became now a matter of considerable interest to ascertain in what way carbolic acid acted in arresting decomposition, and the following experiments were made, with the object of clearing up this point:—

XIII. Albumen was mixed with four times its bulk of water, and a one-per-cent. solution of pure carbolic acid was added to it. No change took place for the first few minutes, but after a little time a white cloudiness was formed, which gradually collected together into a coagulum. On separating this, and exposing it freely to the air, it entirely resisted putrefactive decomposition. The solution strained from the coagulum still contained carbolic acid and uncoagulated albumen.

XIV. The same experiment was repeated with pure cresylic acid. This acid has still less affinity for albumen, the mixed solutions remaining clear for nearly half-an-hour.

It is evident, therefore, that the tar acids do not owe their special action to their coagulating powers on albumen, for the last two experiments show, contrary

to the generally received opinion, that their affinity for this body is but slight.

XV. A few drops of carbolic acid, added to half a pint of sugar syrup and yeast in full action, immediately put a stop to the fermentation.

XVI. Fresh brewer's yeast was washed with a solution of one per cent. of carbolic acid, and then with water. Its power of inducing fermentation in a solution of sugar was entirely destroyed, although no perceptible change in the appearance of the yeast cells could be detected under the microscope. This experiment was repeated several times, and always with the same result, although when the yeast was simply washed in water it readily induced fermentation.

The odour of carbolic acid adhered most pertinaciously to the yeast, and by no ordinary amount of washing and exposure to the air could it be removed.

XVII. Strychnine was added to a mixture of yeast and sugar solution in full fermentation. No visible effect was produced, the evolution of carbonic acid continuing as brisk as before.

The above experiments, some of which were performed by my friend Mr. Spiller, prove conclusively that carbolic acid has a special action on the fermentation induced by organised matter; it not only arrests it instantly when in progress, but it prevents the development of future fermentation.

38. The action of the tar acids was now examined on certain chemical bodies, which are supposed to act by fermentation, in order to see if they were influenced in the same manner.

XVIII. A solution of diastase (infusion of malt) was mixed with thick starch paste, and a one-per-cent. solution of carbolic acid. On gently heating for a short time, the starch was converted into dextrine, as completely as if no carbolic acid had been present.

XIX. Amygdalin was mixed with synaptase (emulsion of sweet almonds) in the presence of carbolic acid. The formation of the essential oil took place with apparently the same readiness as if carbolic acid had been absent.*

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* These last two experiments are confirmatory of a statement in Dr. Lemaire's work "Sur l'Acide Phénique."

The foregoing results show that carbolic acid has no action on purely chemical ferments. These consist of definite nitrogenous compounds acting simply by chemical affinity, and therefore ought not to be classed with true ferments, which are living bodies. It therefore appears that carbolic acid acts by attacking vitality in some mysterious way, and where an effect is merely due to so-called catalytic force, it exerts no interfering action.

39. The action of carbolic acid on vitality was then tested in other ways:—

XX. Cheese mites were immersed in water, where they lived for several hours. A few drops of a solution of carbolic acid containing 1 per cent. added to the liquid, killed them instantly.

XXI. An aqueous solution of carbolic acid was added to water in which a small fish was swimming. It proved fatal in a few minutes.

XXII. A very minute quantity of a weak solution of carbolic acid was added, under the microscope, to water containing various infusoria, such as bacteria, vibrios, spirilla, amœbæa, monads, euglenæa, paramecia, rotifera, and vorticellæ. The acid proved instantly fatal, arresting the movements of the animalcules at once.

These animalcules are the almost invariable accompaniments of putrefactive fermentation. The above experiment has been tried with putrid blood, sour paste, and decayed cheese, and in every instance the destruction of vitality and the arrest of putrefaction have been simultaneous.

XXIII. Caterpillars, beetles, crickets, fleas, moths, and gnats were covered with a glass, the inside of which was smeared with carbolic acid. The vapour proved quickly fatal. It allays the pain caused by the stings of bees, wasps, hornets, and gnats, if applied pure, or in strong solution, to the wounded part.

I find it recorded by Dr. Lemaire and other observers that carbolic acid vapour will also kill flies, ants and their eggs, lice, bugs, tics, acari, mosquitoes, aphides, butterflies, earwigs, wood-lice, cockchafers, centipedes, and other insects of this size; its vapour, however, does not appear to be strong enough to act

injuriously on animals larger than mice. When such animals are killed with it, their bodies dry up in the air, and resist putrefaction for some time.

40. From the intense aversion shown by all insects to the odour of carbolic acid, it is probable that the plentiful use of this agent would effectually preserve cattle from those terrible scourges met with in certain parts of Africa, the zimb and tsetse-fly. The effects following the bite of the latter have been described to me as being almost identical with the symptoms of cattle plague.

M. Lucien Biard, in speaking of the invasions of the large ants of Mexico, says that when one of their battalions threatens his house, he sprinkles a little carbolic acid in front of it. The army immediately makes a detour to avoid the obstacle.

When an animal is killed by the injection of a saturated aqueous solution of carbolic acid into its veins, circulation is instantly arrested, the blood is not coagulated, and no alteration, either in the shape or the appearance of the globules, is detected under the microscope. The only apparent change consists in the immobility of the globules.

41. In the *Annales de Chemie et de Physique* for October last, there is a letter from M. Béchamp to M. Dumas, in which it is said that creosote appears to be the agent which most strongly opposes the development of organic ferments, but that it does not interfere with the living ferments or animacules when they are once developed. This assertion is in direct opposition to all my experiments, about the accuracy of which I have no doubt whatever, having submitted them to repeated tests. The powerful action which carbolic acid exerts on the phenomena of life is the most remarkable property which it possesses. It may be looked upon as the test proper for distinguishing vital from purely physical phenomena, and in most cases its action is characterised by the certainty and definiteness of a chemical re-agent. In the presence of carbolic acid the development of embryotic life is impossible, and before its powerful influence all minute forms of animal life must inevitably perish.

42. It may be considered as definitely proved that the vapour of carbolic acid, in the atmosphere, exerts

a special selective power on all minute organisms possessing life. If the contagious matter of cattle plague is possessed of organic vitality, as must be now admitted, it will be destroyed, beyond the possibility of revival, when brought into contact with the vapour. French experimentalists have repeatedly tested the influence of carbolic acid on vaccine lymph. They have employed lymph both pure and mixed with a trace of carbolic acid. The vaccination with pure lymph was followed by the usual results, but in no single instance was any effect produced by the lymph containing carbolic acid.

43. The following experiment tends to show a similarity between the action of vaccine virus and that of the cattle plague:—

XXIV. The air from a close, highly-infected shed (57.), containing animals in the last stage of the disease, was drawn through glass tubes containing tufts of cotton wool, in the expectation that some of the virus cells, supposed to be floating about in the atmosphere, would be arrested by the wool.

The suction was continued for ten minutes. One piece of the infected wool was then exposed for half an hour to the vapour of carbolic acid. Two apparently healthy calves were selected, and an incision being made beneath the skin, these pieces of wool were respectively inserted in each. The animal thus inoculated with the infected wool, which had been exposed to carbolic acid, remained perfectly well, but the other animal took the disease, and died in a few days.

I place this upon record, although I do not attach much importance to it, as the experiment was made at a farm where the plague was raging; and it is quite possible that the calf which died did not take the disease from the wool. Unfortunately, time would not permit me to verify this experiment so as to place its results beyond doubt. It is likewise desirable to inoculate with the virus itself, collected from the eyes, &c., of diseased animals, mixed with different quantities of carbolic acid. There can be little doubt that the issue would prove satisfactory.

44. I first employed carbolic acid on a large scale early in December last. Considerable experience suggested to me the best way of proceeding, and I consider

that the results have proved that my views were correct. A detailed account of the various experiments is given in the next part.

I had two objects in view; firstly, to apply the energetic disinfecting powers of sulphurous acid for the purpose of purifying the cattle sheds two or three times a week; and secondly, to trust to carbolic acid as a permanent means of protecting the animals from extraneous infection. Sulphur fumigation and carbolic acid agree very well together, and somewhat assist each other's action; whereas oxidizing disinfectants, used either with carbolic acid or sulphurous acid, are inoperative; the energies which should be directed to the destruction of infection being exhausted in neutralising each other. When dealing with such an overwhelming amount of putrefying and putrescible organic matter as is met with in a farmyard, it is of paramount importance to economise as much as possible the disinfectant. I have already shown that chlorine and ozone are very wasteful agents. As it is our chief aim to destroy the activity of cattle plague virus, (the destruction of ordinary farm-yard odours being of secondary importance,) even sulphurous acid is open to objection on the score of waste; but carbolic acid goes direct to the root of the evil, and acts solely where it is most required, without touching the innocuous dunghill stenches. Owing to the power possessed by carbolic acid of arresting and preventing decomposition, it checks the evolution of these offensive odours, and, by retaining the nitrogenous compounds in the manure, it greatly increases its value. At the same time it stops the development in the manure of minute animal organisms, and it has been observed that flies never congregate about dunghills where carbolic acid has been habitually used (100.), whilst the liquid manure which oozes from them is without smell. In stables and cowsheds this property is of very great importance, both as regards the comfort and health of the animals, especially during the hot summer months.

45. Another advantage of carbolic acid, over almost all other disinfecting agents, consists in the fact that its vapour is never injurious or unpleasant to cattle. Indeed, they seem to like it; they lick the woodwork

of their stalls, after it has been sprinkled with the undiluted acid (69.), and will readily drink water in which the acid has been dissolved. If applied to their mouths in its undiluted state, I am told that it will produce temporary blistering; but such blisters are entirely free from danger, and heal very rapidly. From its action on the human skin, if carelessly used, I have no doubt that inconvenience to the cattle might arise; but although carbolic acid has been used freely by me, and by many farm servants under my directions, in the treatment of several hundred animals, I have not had a single instance of this action brought under my personal notice.

If undiluted carbolic acid is allowed to remain on the hands, it will act as a mild caustic. This inconvenience is, however, very slight, and may be avoided with ordinary care. I have had my hands repeatedly covered with carbolic acid during the last four months, without experiencing any painful effect. Ample warning of the approach of blistering is given by a preliminary smarting, and if this is attended to, and the acid rubbed or washed off, no further annoyance is felt. Sweet oil rubbed over will remove the last traces of the acid.

46. Finding that medical and scientific writers were unanimous in the opinion that small internal doses of carbolic acid were attended with no injurious effect, I have recommended the addition of small quantities both to the food and water given to the whole of the stock, sick or healthy, on the farm. This has a two-fold action. The water given to cattle is seldom very pure, and carbolic acid will neutralize any virus of infection which may happen to have found its way into it. Moreover, after drinking aqueous carbolic acid, the breath smells of it for some hours. Now, it is very probable that the germs of infection enter the animal system through the mouth (17.), and by thus loading the breath with the antidote, it is reasonable to suppose that these germs would be destroyed before they had an opportunity of doing harm. The vapour of the acid, diffused through the air, will kill large insects; it is reasonable, therefore, to suppose that it will much more readily destroy microscopic germs when brought into contact with its vapour during respiration. Be-

sides. it is not unlikely that after the system has become habituated to repeated doses of carbolic acid, it will acquire additional power of resisting the first attack of disease.

Since this investigation was undertaken, I have made a collection of cases, illustrating the good effect of carbolic acid in arresting the spread of the cattle plague in various parts of England and the Continent. I will not, however, enter into particulars, but confine myself to those cases which have come under my own immediate knowledge.* I have not yet met with a single instance in which the plague has spread on a farm where this acid has been freely used.

On the Adulterations of Carbolic Acid, and their Detection.

47. The official recommendations (50.) have naturally brought into the market many substitutions for carbolic acid, in which the valuable agent is diluted with cheap inert bodies, whilst the price charged, in some cases, is higher than that of the genuine article. Specimens of two such substitutions, called cresyline and carboline, were forwarded to the Royal Cattle Plague Commission for approval, "as being more certain disinfectants than most of the carbolic acids now being sold to the public, many of which contain but a very small per-centage of that acid." It was stated that the preparations contained over 60 per cent. of carbolic acid, and were miscible with water. As it was possible from these and other reputed advantages that the preparations might be of considerable value, they were forwarded to me for examination. Cresyline consists of alkaline water, and tar oils boiling above 370° C., therefore containing little or no carbolic or cresylic acids. Carboline is a dilute solution of caustic soda, containing 4·1 per cent. of

* It may, however, be of interest to state that carbolic acid was the principal substance used in the Jardin d'Acclimatation, in the Bois de Boulogne, to prevent the spread of the disease amongst the animals in that establishment. According to the *Journal of the Society of Arts* for April 13th, 1866, more than twenty pounds of this acid were used daily, in washing the walls and mangers, and in sprinkling the floors of the stables and enclosures, and it is to its constant use that the arrest of the malady is generally attributed.

carbolic acid. The price of these preparations is higher than that ordinarily charged for good commercial carbolic and cresylic acids.

Other creosote samples from different makers were found to contain respectively 4·5, 2·6, 5·9, and 4·2 per cent. of carbolic acid, the rest being tar oils. In other instances, articles have been sold as commercially pure carbolic acid, which were found to contain from 30 to 50 per cent. Frequently a very fœtid sulphur compound is allowed to remain. This should be avoided, as although the antiseptic powers of the liquid are great, the offensive odour which it diffuses round the neighbourhood is excessively nauseous.

48. It is by no means difficult to detect the adulterations referred to above. Commercial carbolic acid is soluble in from 20 to 70 parts of water, or in twice its bulk of a solution of caustic soda, while oil of tar is nearly insoluble; but if the amount of carbolic acid be increased some remains undissolved.

To apply the tests:—1. Put a teaspoonful of the carbolic acid in a bottle, pour on it half a pint of warm water, and shake the bottle at intervals for half an hour, when the amount of oily residue will show the impurity. Or, dissolve one part of caustic soda in ten parts of warm water, and shake it up with five parts of the carbolic acid. As before, the residue will indicate the amount of impurity.

These tests will show whether tar oils have been used as adulterants; but to ascertain whether the liquid consists of a mere solution of carbolic acid in water or alkali, or whether it contains sulpho-carbolic or sulpho-cresylic acids, another test must be used, based upon the solubility of these, and the insolubility of carbolic acid, in a small quantity of water. In this case proceed as follows:—2. Put a wineglassful of the liquid to be tested in a bottle, and pour on it half a pint of warm water. If the greater part dissolves, it is an adulterated article. Test the liquid in the bottle with litmus paper; if strongly acid it will show the probable presence of sulpho-acids, whilst if alkaline it will show that caustic soda has been probably used as a solvent.

These tests are not given as having any pretensions to scientific accuracy, but as affording persons who

are desirous of using carbolic acid, and are willing to pay a fair price, a rough and ready means of seeing if they are being imposed upon.

If greater accuracy in the tests are required, recourse should also be had to distillation with a thermometer—carbolic acid boils at 184° C., cresylic at 203° C., whilst xylic acid (96.), which may possibly be present, and has great antiseptic value, boils at 220° C. Reichenbach's pure creosote (33.) boils at 219° C.

PART III.

DISINFECTING EXPERIMENTS ON THE FARM.

49. For all practical purposes infection may be considered as radiating from a focus, and following the same law as other radiant forces. At the centre, which may be a diseased animal, an infected shed, or farm, the danger is at its maximum, and it decreases in intensity inversely as the square of the distance from the focus increases. A certain amount of resisting power is unquestionably conferred on an animal by carbolic acid, and it is important to know how near cattle so protected can approach an infected centre and still remain safe. The simplest experiment, and the one most likely to succeed, is to endeavour to protect a healthy farm from the march of the closely investing plague (51. 52. 66. 67.). Here the resisting power is at its maximum, whilst the intensity of the infection is at its minimum. Next, in order of severity, is the test of stopping the plague when it has invaded a farm (58. 60. 68. 72.). A yet severer test is the attempt to prevent the communication of the plague to a healthy animal when kept by itself in an infected shed, or to protect a healthy animal placed by the side of a diseased one (54. 59. 65.). Lastly, in order of severity, is the attempt to counteract inoculation, and to destroy the virus when it is actually present in the system of the animal (77. to 96.). Viewed in one light, this latter experiment belongs to medical science, a subject which is out of my province, but, in another light, it is merely the last link in the chain of experiments on disinfection, and as such clearly within the domain of achemist.

It was to test the value of disinfection, under the various circumstances here referred to, that I was authorised to proceed to infected districts and carry out practical operations at farmhouses.

Plan of Disinfection Recommended.

50. I have not thought it necessary to give any detailed recommendations concerning the best method of utilising the valuable antiseptic properties of carbolic and sulphurous acid, since the official recommendations for disinfection, issued by the Royal Commission on February 23rd, are very explicit on that point. With a few alterations, suggested by wider experience, they will agree perfectly with my plan of proceeding.

Experiments at Mrs. Carmichael's Farm.

51. This farm is situated about three miles from Thirsk, in Yorkshire. In November last I first heard that the disease had attacked several farms in the neighbourhood. I at once sent down a supply of carbolic acid, with minute instructions for its employment. Hearing shortly afterwards that the disease was rapidly spreading round the farm, I went down to Thirsk, personally to instruct the farm-servants in properly carrying out my plan. I found the disease was making terrible ravages on adjoining farms; the death-wave had rolled across the country up to these herds, and, judging from the virulence the disease had already manifested, there could be little doubt that Mrs. Carmichael's farm would speedily be attacked. I found twenty-five heads of cattle on the farm, all in perfect health. The cow-sheds were well cleaned out, whitewashed with lime and carbolic acid, fumigated with sulphur, and thoroughly sprinkled over the floors, walls, and rafters with carbolic acid. The manure in the fold-yard was watered with a one-per-cent. solution of carbolic acid, and the open sheds were also well sprinkled with the undiluted acid. The horns, legs, feet, tails, &c., of the cattle were painted over with the aqueous solution, by means of a brush, every night and morning; the clothes of the men were also sprinkled with the liquid, and they

were told occasionally to dip their hands in it. Pieces of carpet, matting, sacks, &c., were hung up in the sheds, and were kept wetted with carbolic acid.* Instructions were left for the whitewashing to be done every fortnight, the fumigation with sulphur twice a week, and the other operations daily.

On visiting this farm a second time, I found that my instructions had been carefully carried out, and although nearly every other farm in the neighbourhood was severely visited with the disease, this was unattacked. This exemption is the more remarkable, as on an adjourning farm, held by a near relative, many cattle died; and during the whole of the time there was frequent communication between the two families.

Up to the date of this report, Mrs. Carmichael's farm has kept free from the plague, and is now, I believe, the only one that has escaped for some miles round. Owing partly to the vigorous carrying out of the late Act, and partly to there being fewer animals for the disease to attack, the plague is now leaving the neighbourhood.

Experiments at Sir G. Wombwell's Farms, Newburgh, near Thirsk.

52. On February 17 I superintended the thorough disinfection of Sir G. Wombwell's Home farm, and left full written instructions with his bailiff. This farm and one about a mile off, belonging to Mr. Easton, were the only farms in that neighbourhood free from the disease. On the same day I superintended the disinfection of Mr. Easton's farm. My instructions have been carefully carried out, and notwithstanding the ravages of the disease all round, it has kept off these two farms.

Experiments at Mr. Daniel's.

53. This is a very large farm at Oulston, ten miles from Thirsk. When I first arrived there I found the

* For some of these practical hints I am indebted to my friend, Professor A. H. Church, who was, I believe, the first to publicly recommend the employment of carbolic acid as a preventive against the cattle plague.

disease raging violently; out of a herd of sixty-six on February 1, forty-five only remained by the middle of the month, and fresh cases of illness were being reported daily. Owing to the extent, and very inconvenient arrangement of the premises, I felt that it would not be a fair trial to attempt to stop the plague on this farm, as the buildings were already saturated with infection, and all the details required for an accurate experiment could not be properly carried out. Permission was asked, and freely given, to try certain other experiments here.

54. A shed was selected some distance from any other building, which had been used as a hospital for the cattle as they fell sick; several had died in it, and it then contained a diseased animal almost moribund; no system of disinfection had been adopted, and the stench was very bad. The sick beast having been removed and tethered to an outside wall, the litter was cleared away, and the floor washed with a two-per-cent. solution of carbolic acid. The walls, roof, and rafters were then whitewashed with freshly burnt lime, a pint of carbolic acid being added to each pailful of whitewash. The floor, after cleaning, was thoroughly sprinkled with undiluted carbolic acid, and the woodwork and inside of the door rubbed with a cloth dipped in the same. The ventilating holes were then stopped up with hay, and the door being kept shut, one pound of stick sulphur was burnt on a shovelful of red-hot cinders placed in the middle of the floor. After two hours, on opening the place, it was found full of a thick white vapour, which disappeared in the course of half an hour. In the meantime, Mr. Hain, veterinary surgeon, of Thirsk (to whom I am under many obligations for valuable advice and assistance in the course of these experiments), had procured a healthy two-year old bullock from a farm about two miles distant from any infection. The diseased animal, formerly occupying the shed, was then tied to a stake at the end of the shed, whilst the healthy animal was fastened up near the door. Directions were left to continue treating the sick beast as hitherto, and to give the healthy one fresh hay and water, mixed with one ounce of carbolic acid per diem. The shed was to be well sprinkled daily with carbolic acid, all over the

floor and walls, as high as could conveniently be reached, and to be fumigated with sulphur once a week, and whitewashed every fortnight, as long as the experiment lasted. The farm was visited every day for a week, and on leaving I gave full written instructions to Mr. Daniel, who promised to attend personally to the experiment. Mr. Hain also promised to ride over two or three times a week, and report progress.

55. In a few days it became evident that the experiment would be much more severe than had been intended. The size of the shed, fifteen feet by nine feet, was insufficient to prevent the animals touching occasionally; the hind quarters of the healthy beast were soiled with the liquid alvine discharges from the diseased one, and on one occasion the former was seen to lick a part so smeared. Actual inoculation, therefore, might be considered to have taken place, and the question now became, how great a power of resisting the infection would the carbolic atmosphere, which the animal was breathing day and night, confer upon it. Absolute immunity was scarcely to be hoped for, and all that now remained was to see how long the means employed would enable the animal to withstand the disease.

56. The animals were put together on February 15. On the 21st the diseased one died in the shed; its body was removed, and replaced the next day by another sick animal. For a month the experiment progressed satisfactorily, when the healthy animal showed signs of illness, but in a very mild form, and in a few days recovered.

This experiment although not so satisfactory as if the animal had entirely resisted infection, is, so far as it goes, very striking and valuable. Allowing nine days for the period of incubation, it shows that the antiseptic powers of sulphurous and carbolic acids ensured absolute immunity for nearly three weeks, and finally, when the animal did succumb to this very severe test, deprived the disease of its malignant character. The relative position of the animals in the shed was unfortunate. The healthy animal being close to the door, the man who looked after the diseased animal and brought it food was obliged to pass close

to it daily. Also the filth and droppings from the diseased animals had to be passed out daily close to the healthy one, and the dead bodies were likewise dragged out in the same way. Actual contact between the healthy animal and infected matter must therefore have repeatedly taken place. Considering the crucial severity of this trial, it is a very encouraging fact to have warded off an attack for so long a time.

57. On February 15 I selected, at the same farm, another small shed containing three animals in the last stage of the disease, and in which several had previously died in rapid succession. The place had not been cleaned out for some time, and was pervaded by the characteristic stench of the disease. In this shed I spent the greater part of the day, collecting specimens for future examination.

a. Several tubes of air from different parts of the shed, and from the nostrils of a dying cow, were collected and sealed up before the blowpipe.

b. Tufts of cotton wool having been pressed into glass tubes, air from the cow's nostrils and from different parts of the shed were sucked through them severally for ten minutes.

c. A very clean flask was filled with ice, a clean cup suspended beneath it, and the whole hung up to a beam in the centre of the shed, just out of reach of the animals. The moisture, condensing on the outside of the flask, dropped into the cup, and was preserved in a clean stoppered bottle. It took thirty-six hours to collect a quarter of an ounce of liquid.

d. The air of the shed was likewise examined by shaking it, in a bottle of known capacity, with a standard solution of permanganate of potash; but as no two determinations were obtained at all near to each other, nothing was shown by these experiments, except that air taken from close to the animals' mouths was more charged with organic matter than that taken from other parts of the shed.

The tubes of air, cotton wool, and condensed vapour were forwarded to Dr. Angus Smith, who kindly undertook their examination.*

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* See Dr. Angus Smith's Report, Part II.

Mr. Bainbridge's Farm.

58. This farm is likewise at Oulston, close to Mr. Daniel's, where the disease was spreading with the greatest virulence. It had broken out here a few days before I arrived. The original stock consisted of forty-one fine healthy beasts. The farm-buildings were kept beautifully clean, no pains or expense had been spared to keep the herd in good health, and Mr. Bainbridge was willing to adopt any means likely to save his stock. In the four days between the first outbreak and my visit, three animals had died, one was ill, and another suspected. Disinfection was immediately commenced by whitewashing and sprinkling with carbolic acid, and burning sulphur, substantially in the way recommended in the official recommendations. In effecting this, I was ably seconded by Mr. Bainbridge and his very intelligent foreman, Mr. Hardcastle, both being unremitting in their endeavours to carry out the experiment in a satisfactory manner.

Some little delay occurring in procuring a sufficient supply of carbolic acid, the whole of the buildings could not be thoroughly done until nearly a week later. Then, after the animals already diseased had died, the plague left the farm, and, up to the present date, no further attack has taken place.

59. The hospital shed, to which Mr. Bainbridge's cattle had been removed when they exhibited signs of illness, and in which three had died, being in a field a quarter of a mile away from any other building, was well adapted for experimental purposes. Permission being freely given to make what use I liked of it, I had it thoroughly cleaned, and disinfected with carbolic acid, whitewash, and sulphur, in the manner already described (54.). A two-year-old bullock, from a farm a mile distant from any disease, was put into one of the stalls, and in the adjoining stall a diseased heifer was tied, in such a manner that actual contact was impossible. When, a few days after, this died, there being no other case to substitute for it, the healthy beast was kept by itself. Sprinkling with carbolic acid, sulphur fumigation, and whitewashing

were strictly carried out, and for nine days the experimental bullock remained healthy. It then showed signs of disease, and died on the thirteenth day.

Miss Barroby's Farm, Dishforth.

60. The experiments here have been conducted with greater accuracy than was possible at other places, and the results consequently are more striking. On February 20 I accompanied Dr. Ryott, of Thirsk, to this farm, where the disease had broken out amongst a valuable herd of pedigree short-horns. The animals appeared to be tended as carefully as if they had been hunters. The buildings were scrupulously clean, the only fault being their close proximity, which rendered a proper separation of the diseased from the healthy impossible. The only available part of the premises, where the graves could be dug, was also too near the houses, and many of the carcases had to be dragged close by the doors where healthy beasts were confined. A very valuable large red bull, owing to the position of his house, was especially in danger To attend to the sick beasts, certain men had been told off, and were even provided with a special sleeping apartment in the house, and no communication whatever was permitted them with the other farm servants.

I took some carbolic acid with me, and at once instructed the farm servants in its use, and directed the preparation of whitewash and fumigation with sulphur. Not having sufficient acid to disinfect the whole of the premises, a large supply was ordered, and attention was chiefly directed to the houses containing the healthy stock, more especially to that of the large red bull.

61. The virulence of the disease may be judged of by the following tabular statement:—

Total number of beasts, 32.

January 24.—A severe case: recovered.

February 2.—One animal attacked: died on the 3rd.

7th.—One animal attacked: died on the 11th.

13th.—Six ill.

15th.—Nine ill.

20th.—Visited Dishforth.

23rd.—Five ill. Seven dead.

February 25th.—Four killed by order of inspector. Three ill. Two new cases.

26th.—Two killed.

27th.—The whole of the premises were thoroughly disinfected with carbolic acid and sulphur, according to written instructions.

62. From this date the disease suddenly stopped. Two young bulls and two cows, ill before the disinfecting operations had commenced, were subsequently killed by order of the inspector; but no fresh case occurred, although the disease continued to attack neighbouring farms as severely as before.

63. Dr. Ryott, who spared no trouble to have these experiments properly carried out, and to whom I am greatly indebted for his kindness in superintending them during my absence, has kept me constantly informed of the results. At the date of this report, all the animals are looking remarkably well and healthy; not one fresh attack having take place since February 27, when disinfection was effectually commenced.

The convalescent cows are now intermixed with those which have escaped the disease, and of the latter, two about to calve are tied up in the house where three animals had died; some also are kept in houses from which diseased animals were removed.

The large red bull, which now occupies a shed wherein were formerly a diseased cow and heifer, is thriving, although both the sick animals had to pass the open end of his shed on their removal from the other houses, and the dead were conveyed by the same road to their burial. All this time the disease keeps in the village; fresh outbreaks are reported frequently; and on some farms, nearly every head of cattle is swept off.

Dr. Ryott having examined the milk, and found it free from taint, two of the convalescent cows are now supplying the family daily with milk, cream, and butter.

The man who was principally employed with the diseased animals is now attending to the lambing of the ewes; as yet they are all well, and show no signs of illness.

64. Dr. Ryott writes, under date March 27, "There can be no doubt of the value of the plan of disinfec-

tion, after what I have observed in such a severely plague-smitten place as Dishforth, not only in the protection of cattle, but also of sheep—as ewes at lambing time would be most susceptible. But the plan of disinfection may be brought into disrepute by being either improperly or insufficiently applied. For instance, hearing that a farmer in whom I took some interest had got the disease amongst his cattle, I called on him, and found several ill, and some already dead. I recommended the plan of disinfection as a protection to the healthy animals in another fold, and, as a beginning, gave him a gallon of carbolic acid. A week after I visited him, and found that several animals had been killed, and others were ill, waiting the executioner. He said he had tried everything, but particularly the treatment of Mr. Worms, and had used the disinfectant plan. On inquiry I found that not more than *half a pint* of the carbolic acid had been used, out of the gallon I gave him ; and yet he said he had tried the plan, and had given out that it had failed."

65. An opportunity was afforded at this farm of trying a somewhat important experiment. A shed in which two cows had died was disinfected (54.), and a short-horn cow—a prize beast — which had calved about a week, and had just shown signs of disease, was shut up in it. As the yield of milk had not stopped, a healthy calf was put in the same house, and allowed to suck the diseased cow during the whole time she lived ; the only precaution taken being to keep the atmosphere of the house strongly smelling of carbolic acid. This experiment was unfortunately cut short by the inspector insisting on the slaughter of the cow, although she had then almost recovered from the disease. This happened during my absence, notwithstanding the energetic remonstrances of Dr. Ryott, who explained that it would interrupt a valuable experiment, and that I was empowered to reserve infected animals for such purposes. Since the cow was killed (March 3) the calf has remained well and lively in the same house, and has been fed with milk from another cow which was recovering from the disease. It is much to be regretted that this experiment was not allowed to be properly carried out,

but, incomplete though it be, it is of great value, especially when viewed in conjunction with the other operations on the same farm.

Mr. Spence's, Smedley, near Manchester.

66. I arrived here in December last, and instructed the attendants in the management of the disinfecting plan with carbolic acid and sulphur. It has been regularly carried out ever since. In January last the disease first appeared in the immediate neighbourhood, and carried off about a dozen cattle from a farm, the sheds of which were not more than 500 yards from Mr. Spence's cows. A short time after, thirty beasts, 750 yards off on another side, were attacked, and the whole were swept off in rapid succession. A month ago the disease appeared amongst twenty-two in another direction, not more than fifty yards off, and the whole of these also died. Mr. Spence's cattle still keep well, and as the disease is leaving the neighbourhood, there is every probability that they will remain healthy.

Mr. Thornton's Farm.

67. This is situated at Clayton Bridge, near Manchester. The stock consists of ten milch cows, and the shed containing them has been regularly disinfected with carbolic acid since Christmas. No case of illness has occurred, although on the adjoining farms the disease has been rather severe for some months.

Mr. Lowe's, Smethwick Hall, Brereton, Cheshire.

68. This farm is in the centre of one of the most affected localities in England. The stock consists of seventy-three animals; forty-five milch cows, kept in houses which have been regularly disinfected since December last; and fifteen two-year-old heifers, and thirteen yearling calves, kept in fields and open sheds. To these latter, no disinfectant whatever has been

used, owing to the impossibility of applying it satisfactorily to animals in the open air.

69. The disease prevailed very severely all round, but no case occurred at Mr. Lowe's farm until February, when one of the forty-five milch cows showed signs of illness. Immediate investigation was made, and it was found that one of the cowmen, on the previous day, had attended a post-mortem examination of some diseased beasts, and having come directly to Mr. Lowe's houses, afterwards had milked some of the cows. The man was of course discharged instantly. The succeeding day, February 20, the first cow that the man had milked, on the day of the post-mortem, refused her food, and all the symptoms of the plague rapidly appeared. Two others in the same house were afterwards attacked, one of which recovered almost immediately; the other was killed as a matter of precaution. A fourth case then occurred in another shed. On inquiry, I found that the first, third, and fourth cows were those which had been milked by the discharged man. The second case, occurring in the same shed with the first and third, was evidently either developed from them, or was a case of infection brought from the calves mentioned below (70.). These four cases are all that have occurred amongst the forty-five milch cows in the disinfected sheds. Up to the present date the rest are perfectly well. Their health, indeed, seems to be improved by the carbolic acid. The cows are very fond of it, and lick it from the woodwork or walls whenever they have an opportunity.

70. Previous to his discharge, and on the morning of that day, the same man was employed in preparing food for, and feeding, the unprotected fifteen heifers and thirteen calves. A few days after the disease developed itself amongst them, and in a fortnight they were all dead.

71. A crucial experiment has, therefore, been tried at this farm on the grandest scale. It was, indeed, supplied by accident, but it is none the less satisfactory and decisive. Although it far surpasses in magnitude any trial which an experimentalist dare institute, it fulfils every condition which could be demanded by the most rigid investigator. A farm is chosen in the

very hotbed of cattle plague. The cattle on it are divided into two lots, forty-five being placed in disinfected houses, and twenty-eight in undisinfected open sheds. The disease is brought into each lot, on the same day, by direct inoculation of the virus. Of the disinfected animals, only those actually inoculated fall a prey, whilst of those which are not protected by disinfection the whole are rapidly swept off.

It is scarcely possible to say anything which will add to the satisfactory nature of these results; but I may mention that of the ten farms immediately surrounding Mr. Lowe's, seven have lost the whole of their stock (amounting to 215), whilst on the remaining three the plague is gradually spreading through the herds.

[Accident has carried this grand experiment a step further, with the most striking results. A few weeks ago the remainder of Mr. Lowe's forty-five disinfected animals were turned out to grass, and at the same time were removed from the protecting influence of the carbolic acid. Within a few days the plague attacked and killed the whole of them. The complete proof of the value of carbolic disinfection which has been afforded at this farm is cheaply purchased at the loss of all Mr. Lowe's stock.—W. C., May 11, 1866.]

Mr. Tollemache's Farms, Cheshire.

72. On February 28 I visited Peckforton Castle, at the courteous invitation of J. Tollemache, Esq., M.P. for South Cheshire. Owing to the long continued severity of the disease in this part of the county, the only available farm, on which I could try the value of the disinfection plan, was the Home farm at the foot of the Castle Hill. I attribute the immunity which this farm has hitherto enjoyed to the protection afforded by the height and well-wooded character of the rock guarding it on one side, and also to the care and strict isolation to which the cattle are subjected. About ten milch cows are kept in one house, and an equal number of cattle in a field and in open sheds. At the time of my arrival, Mr. Tollemache considered that his herds were in imminent danger, the disease

existing all round, and rapidly advancing towards his farm in three directions; a row of small cottages, each having one cow, formed a train connecting a diseased farm, about half a mile off, with the Home farm. Adjoining Mr. Tollemache's farm, and forming in fact part of the same establishment, are some cattle belonging to Mr. Smith, the sheds of which are within fifty yards of Mr. Tollemache's sheds. Attention was first directed to the house containing Mr. Tollemache's best milch cows, which was thoroughly cleaned, whitewashed, fumigated with sulphur, and freely sprinkled with carbolic acid. Sacking soaked in the acid was hung up in different parts of the shed, and the water supplied to the cattle was likewise impregnated with it.

73. Beyond sprinkling carbolic acid about the sheds, no disinfection was attempted with the other cattle, it being considered difficult to guard them from infection, so long as they lay out in fields and opensheds (68.).

The small cottages were then visited. Their cow-houses were whitewashed, sulphured, and treated with carbolic acid in the usual way. A sufficient supply of the acid was left at each cottage, with full instructions for its use. Nothing was done to the cow-houses of Mr. Smith, who professed little faith in disinfection.

74. The disease still advanced steadily towards the Home farm, and on March 12 one of Mr. Smith's cows was attacked; she was not removed, but kept in the same house with the healthy ones. Then, for the first time, carbolic acid was used in the shed, but in very sparing and insufficient quantities. The disease spread, and at the present date five have died and three recovered.

75. Up to March 26 the whole of Mr. Tollemache's cattle remained in health. On that day, however, a young bull, lying in the open yard (one of the lot which had not been disinfected), was thought to show symptoms of illness; it was put into a shed by itself, and on the 28th it died of the plague. No other case of disease has since occurred amongst the cattle lying in the partially disinfected, open sheds, and as a month has elapsed since this bull died, the period of incubation has long passed, and it is certain that no germs of

plague from that source are lurking in the systems of the remaining animals.

On April 7 one of the milch cows was taken ill in the disinfected shed; however, she recovered in a few days, and is now amongst the other cows, and gives as much milk as before. This case is easily accounted for, as since March 12 the milch cows have been exposed to several cases of disease within fifty yards on one side of them at Mr. Smith's (72.), whilst at the latter end of March a bull actually died of the plague within a few yards of their shed. Notwithstanding the care which doubtless was taken to avoid communicating infection from the sick to the healthy animals, the virus may easily have been carried to one of the milch cows whilst they were being driven across the yard to water, as was done once or twicea-day.

76. Even the wonderful disinfecting powers of carbolic acid are probably put to too severe a test, when it is expected to preserve cattle from taking the disease brought to them in so direct a manner as was the case on this farm; but it may be considered as almost proved (56. 69. 75.), that when the plague does enter a shed which for some time past has been properly disinfected with carbolic acid and sulphur fumigation it loses much of its virulence, and is deprived of its infectious character.

All the cows at the small cottages which have been disinfected since the beginning of March remain healthy, although they are now quite surrounded with the disease, and are even more exposed to the danger of infection than are those at the Home farm.

PART IV.

EXPERIMENTS ON THE INJECTION OF ANTISEPTICS INTO THE BLOOD OF DISEASED ANIMALS.

77. Although perhaps there is no actual cure as yet known for the cattle plague, any more than for smallpox and similar diseases, yet on theoretical grounds it appeared not improbable that good might be done by injecting various antiseptics into the blood (49.). If the disease depend on a change in the blood, analo-

gous to fermentation (8.), induced by the presence of certain virus-cells, it appeared likely that such antiseptics as sulphite and bisulphite of soda, or carbolic acid and its homologues, might stop this action, if they were introduced in adequate quantity, without acting injuriously on the health of the animal. Professor Polli, Dr. De Ricci, Dr. M'Dowall, Dr. Waters, and others, have advantageously used sulphites and bisulphites as prophylactics in zymotic diseases. Viewing the matter solely from a chemical point of view, it appeared feasible that, as I had successfully attacked the floating germs of the disease by atmospheric disinfectants, so I might neutralise the virus in the blood by the introduction into it of appropriate antiseptics. The experiments have been tried upon too limited a number of animals to be worth much. I, however, put all these trials on record, as the results may prove of some service to others who may be enabled to continue them.

73. The first experiments were performed on March 2 at Mr. Findlow's, Wardle Hall, Cheshire, on two heifers in calf, just taken ill. The temperature of the animals per rectum was, No. 1 106°·2 Fahr., No. 2 106°·1 Fahr. The jugular vein having been opened with a fleam by Mr. Dunn, veterinary surgeon, (to whose assistance in these experiments I am much indebted), the flow was stopped by pressing the finger on the distal part of the vein, whilst I inserted the nozzle of an injection syringe (specially made for this purpose) into the vein, pointing towards the heart. The liquid injected consisted of half an ounce of sulphite of soda dissolved in three ounces of water. The temperature of the liquid and syringe was as near as possible 100° Fah., and the act of injection was performed very slowly; particular care being taken to avoid injecting air into the vein. The vein was then fastened up by the surgeon. Two or three men were necessary to hold the animals, as they struggled somewhat, but as soon as the operation was over they seemed as well as before, and suffered no inconvenience from it. The next day the animals were certainly no worse than they were on the previous day, and their temperature had diminished, No. 1 being 106° Fahr., and No. 2 104°·8 Fahr.

79. The good effect of the injection now seemed exhausted, the heifers rapidly got worse, and in a few days died. The disease had visited this farm very severely, only sixteen cattle having been saved out of 107.

Mr. Singleton's Farm, The Rookery.

80. The disease on this farm was also very virulent. Of an original stock of about sixty not one of those attacked had recovered. At my first visit over forty had been buried, and the rest were going rapidly. I was anxious to try the effect of injecting sulphite of soda, and for this purpose, on March 2, Mr. Singleton kindly placed at my disposal four two-year-old heifers which had shown first symptoms of illness that morning. The experiments at Mr. Findlow's having shown that the injection of half an ounce of sulphite of soda into the blood of an animal would do no harm, but would possibly do good (as in each case it was followed by a diminution of temperature), I determined to increase the dose; three-quarters of an ounce of sulphite of soda dissolved in three ounces of warm water were accordingly injected into the jugular vein of each of these animals, their temperatures before the operation being:—

	Deg.		Deg.
No. 3 .	105·2 Fahr.	No. 5 .	104·0 Fahr.
„ 4 .	104·2 „	„ 6 .	102·6 „

On visiting them the next day they were reported to be a little better, an improvement corroborated by the thermometer, which registered as follows:—

	Deg.		Deg.
No. 3 .	102·8 Fahr.	No. 5 .	101·9 Fahr.
„ 4 .	103·7 „	„ 6 .	100·8 Fahr.

The promising symptoms, however, did not last; Nos. 4 and 5 died on March 4, and on the 5th the surviving animals were worse. The injection, as in the former cases, resulted only in temporary good. (79).

Another calf, No. 7, taken ill that morning, its temperature being 106°, was then injected with one ounce of sulphite of soda. In this case it was intended to inject it with another ounce the next day.

81. Sulphite of soda producing no injurious action

when added to the blood (even if it did but little good), it was determined to try bisulphite of soda, on calf No 8, its temperature just before the operation being 104°.

On March 6 I found No. 3 dying; No. 6 about the same as the day before, and Nos. 7 and 8 decidedly better. Their temperatures were :—

	Deg.		Deg.
No. 3 .	98·5 Fahr.	No. 7 .	104·0 Fahr.
„ 6 .	102·4 „	„ 8 .	100·4 „

No. 3 died the same day. Nos. 6 and 7 had each one ounce of sulphite of soda injected into the jugular vein on the other side of the neck; and No. 8 had half an ounce of bisulphite of soda again injected into it.

I was now obliged to leave this part of the country for some days, and, on my return, I found all my patients dead.

82. The following is a tabular statement of the progress of these cases :—

Table showing Results of Injecting Sulphite and Bisulphite of Soda into the Blood of Animals suffering from Cattle Plague.

Number.	Substance injected.	Temp just before injection.	2nd Day.	3rd Day.	4th Day.	5th Day.	—
		°F.	° F.		°F.		
1	½ oz. of sulphite of soda.	106·2	106·0	—	—	Died.	
2	½ oz. ditto	106·1	104·8	—	—	Died.	
3	¾ oz. ditto	105·2	102·8	—	—	98·5; died this day	
4	¾ oz. ditto	104·2	103·7	Died.			
5	¾ oz. ditto	104·0	101·9	Died.			
6	¾ oz. ditto	102·6	100·8	—	101·2	102·4; 1 oz. of sulphite of soda	Died on 6th day.
7	1 oz. ditto	106·0	104·0; 1 oz. of bisulphite of soda	—	—	—	Died on 6th day.
8	½ oz. of bisulphite of soda	104·0	100·4; ½ oz. of bisulphite of soda.	—	—	—	Died on 6th day.

83. Two things are clearly shown by this table. In

the first place, the course of the disease was decidedly checked. In Mr. Singleton's painfully-acquired experience of the effect of the plague, such an occurrence as this had not happened before. In almost every case the course of the disease had been remarkably uniform. An animal was observed to show signs of illness one morning, the next day it was worse, and on the third or fourth day it invariably died. Now, Mr. Singleton himself pronounced each animal treated by injection better the next day, and a reference to the table shows that the thermometer confirmed this decision. Moreover, the amount of this decrease of temperature bears a relation to the quantity of antiseptic used. Thus, when half an ounce of sulphite was injected, the average fall of temperature in the next twenty-four hours was 0·75° F. With three-quarters of an ounce, the fall in twenty-four hours was 1·7° F. With one ounce, the fall was 2° F., whilst with half an ounce of bisulphite of soda, the fall in the same time was 3·6° F.

84. In the second place, not only did the injection effect a temporary good for twenty-four hours, but it caused the animals to survive longer. On this farm, when an animal was taken ill, death ensued generally within four days. But on referring to the table (82.) it is seen that No. 3 (which had received the smallest quantity of antiseptic) lived one day longer than usual. No. 6 (which had received a little more antiseptic injection) lived two days longer than usual; whilst Nos. 7 and 8 (which had received the largest quantity of antiseptics) lived four days beyond the usual time. In all probability, if time had allowed further experiments, so as to find how large a dose of sulphite or bisulphite of soda could be borne in safety by the animals, and especially if they had been kept in disinfected sheds, and received careful nursing and appropriate medical treatment during the progress of the trials—some, if not all, of the cattle under experiment would have been permanently cured.

Injection of Carbolic Acid.

85. This was tried at first very carefully, and in dilute solution; the extraordinarily energetic action

exerted by it on vital phenomena rendering it not unlikely that its direct addition to the blood of an animal already weakened by the disease would be rapidly fatal. The first experiment was tried at Mr. Fenna's, near Beeston. Three ounces of a solution of carbolic acid, containing one per cent., were very slowly and cautiously injected into the jugular vein of a heifer (No. 9) just beginning to show signs of the disease. It appeared no worse for the operation. The next day it seemed about the same; but Mr. Fenna, having in the meantime obtained some medicine reputed to be infallible, was unwilling to allow me to continue the experiment.

86. At this farm I was fortunate enough to find a severe case of the plague in a small, well-closed shed. The peculiar odour attending the disease was most offensive. I spent several hours in this shed examining the atmosphere, and collecting specimens as formerly at Mr. Daniel's (49 *a*. *b*.). Infected air was also drawn over microscopic slides moistened with glycerine. The specimens here obtained were forwarded to Dr. Lionel Beale for microscopic examination.

87. I was courteously allowed to make several trials of carbolic injection at Mr. Dutton's farm, near Peckforton; the experiments took place on March 13, and five cows were subjected to the treatment. Emboldened by the previous result (85.), I worked on this occasion with a solution of pure carbolic acid containing four per cent. The first cow (No. 10) was injected with an ounce and a half of liquid, containing twenty-six and a quarter grains of the pure acid. It is probable that this injection was rather too rapidly performed, for the animal appeared distressed by it, and trembled all over; in about three minutes, however, she quite recovered the temporary ill effects.

It appeared evident that if harm were to follow the injection of carbolic acid the mischievous effect would be immediate; but that if the fluid could pass through the heart, without exerting its paralysing action on that organ, and could get into the circulation, no present ill effects need be anticipated. I therefore determined to push these experiments as far as possible, increasing the quantity of carbolic acid until it produced a fatal result.

88. The next operation was on cow No. 11, in which three ounces of solution (containing 52½ grains of pure carbolic acid) were very slowly injected. No bad effect followed.

89. Increasing the dose, cow No. 12 had injected into her vein 4½ ounces of solution (equal to 78¾ grains of carbolic acid); this also was followed by no immediate ill effect.

90. Cow No. 13 was then treated with six ounces of solution (containing 105 grains of pure carbolic acid) in two portions of three ounces each; five minutes interval elapsing between each injection. The first three ounces produced a slight trembling, but not so severe as in the case of cow No. 10; as she seemed better in a few minutes, the second dose of three ounces was injected. This proved too much, or was pumped in too hurriedly; for almost before I had finished, the animal trembled violently; its eyes projected; its breathing became laborious; it fell down and expired.

The result could scarcely be attributed to the accidental injection of air into the vein, for the distress began with the injection of the first syringeful, and was only increased by the second; nor is it likely that this accident would happen twice consecutively. I was particularly careful on this point, and the construction of the instrument rendered such an occurrence scarcely possible with ordinary precaution. It is probable that the injection was performed too rapidly, or that the vital powers were lower than usual.

91. In the case of the remaining animal, No. 14, I decided to inject as large a dose as it would bear, stopping the operation at the first sign of trembling, and delivering the liquid very gradually. The first syringeful caused no bad symptoms, and I had just finished injecting the second dose when trembling commenced. It was rather violent for a short time, but soon went off, and in five minutes the animal appeared as well as before. This cow, therefore, bore without inconvenience the injection of six ounces of a four-per-cent. solution, containing 105 grains of pure carbolic acid.

Careful observations with the thermometer were

taken before each operation. There were no more diseased beasts on the farm, or I should have carried my experiments still further.

92. On visiting the farm the next day I was told that all the animals seemed better, and on testing them with the thermometer (93.), that statement was confirmed. I gave directions that each animal was to be drenched with half a wine-glassful (one ounce) of carbolic acid in a quart of warm water every morning; but in other respects they might be treated as Mr. Tomlinson, a skilful cow-doctor, should direct.

Business now calling me to London, I was unable to watch the further progress of these cases; this is to be regretted. as a series of daily thermometric observations would have been of great value in suggesting further experiments. I had, however, frequent accounts sent me. Cow No. 14 continued to improve slowly, until convalescent. She is now quite well. Nos. 10, 11, and 12 remained in apparently the same state for four days; they then changed for the worse and died. It is not improbable that, had I been able to inject a further quantity of carbolic acid, during the four days in which they were thus hovering between recovery and relapse, it would have turned the scale, and some of them, at all events, would be now alive and well.

93. The following table gives the thermometric observations:—

Table showing Results of Injecting Carbolic Acid into the Blood of Animals suffering from the Cattle Plague.

No.	Grains of Carbolic Acid injected.	Temperature before Injection.	2nd Day.	3rd Day.	—
		°F	°F		
10	26½	105·4	103·8	Better.	Died on 6th day
11	52½	103·8	102·8	Better.	Died on 6th day.
12	78¾	104·8	104·4	Better.	Died on 6th day.
14	105	103·7	103·1	Better.	Recovered.

94. If future experiments prove that injection of carbolic acid, or other antiseptic, will do good, it is an operation very easily performed (78.). I have injected

five animals, and taken thermometric observations, within an hour. Sulphite or bisulphite of soda apparently occasion some pain, as the animals struggle very much. With carbolic acid, I found them tolerably quiet.

95. I have calculated the proportion which the carbolic acid bore to the whole quantity of blood in these operations. Taking the whole amount of blood in the animal at 150 pounds, there were injected into—

No.	10,	one part	carbolic acid	in 40,000	of blood.
,,	11	,,	,,	20,000	,,
,,	12	,,	,,	13,300	,,
,,	14	,,	,,	10,000	,,

It is worth mentioning, incidentally, that in the case of cow No. 14 (which recovered), the proportion of carbolic acid injected into the blood would have been enough to keep from decomposition the whole quantity of that liquid for a considerable time. In Nos. 10, 11, and 12 the proportion of carbolic acid would probably not have been sufficient for that purpose.

96. I am informed by Dr. Calvert that cresylic acid has much less coagulating power on albumen than carbolic acid, and my own experiments (37.) entirely confirm this statement. I have now in preparation in my laboratory a quantity of cresylic acid in a state of purity, to be employed as an injection, if further opportunities of prosecuting these inquiries be afforded me. Xylic acid, the member of the same series above cresylic acid, is also under preparation. This is also a powerful antiseptic, and it is possible that further investigation may show that this body possesses other valuable properties.

Conclusion.

97. In concluding the report of my experiments, I cannot avoid expressing regret that they are not more complete. Had more time been at my disposal, I hoped to have been able to settle certain important questions, relating to the laws of infection, which are necessarily only imperfectly treated in this report.

Experiments of this kind necessarily occupy much time. Weeks have been spent in the fruitless endeavour to find appropriate spots, where satisfactory experiments could be performed; and when all has been arranged, longer time has elapsed before any result could be established, during which period the experiments required unremitting watchfulness, to guard against the manifold sources of error.

98. Were time and opportunity allowed me for prosecuting these researches, I would point out the following experiments, as being likely to yield valuable results:—

a. Continue the examination of the action of carbolic and cresylic acids on insects, animalcules, and microscopic animal and vegetable organisms, and extend it to xylic acid and other powerful antiseptics of this class, such as eugenic acid, methyl-oxy-phenic, and methyl-oxy-cresylic acids, &c. (36. 39. 40.).

b. Try various methods of readily disinfecting sheds, cattle trucks, &c. It is probable that the liquid pulverisers, as used for the inhalation of medicated liquids, would rapidly diffuse carbolic acid, pure or in solution, wherever its action was needed. The employment of this instrument will also give the means of employing non-volatile disinfectants, such as permanganate of potash, perchloride of iron, and other metallic salts, for purposes of atmospheric disinfection.

c. Examine the atmosphere from different parts of infected sheds, with standard solutions of permanganate of potash, and estimate quantitatively the organic matter therein contained (57. *d.*).

d. Draw infected air through gun cotton, and afterwards dissolve the latter in ether, or other appropriate solvent, and examine the residue under the microscope (57. *b.* 86.).

e. Collect the exhaled breath from diseased animals and cause healthy animals to breathe it. (This experiment must be carefully arranged, so as to avoid communicating infection by other means than through the lungs.)

f. Draw infected air from sheds, and the breath of diseased animals, through spiral glass tubes, artificially cooled with ice, or by Krohne and Sesemann's

ether spray apparatus, as used for local anæsthesia. Examine the condensed liquid chemically and microscopically (57. *c.*).

g. With the condensed liquid obtained in the last experiment, inoculate healthy animals, both before and after mixing with it carbolic acid or other antiseptics.

h. With the liquid collected from the eyes and nostrils of diseased animals, inoculate healthy animals, both before and after mixing with it various quantities of carbolic acid or other antiseptics (42.).

i. Inoculate healthy animals with infected cotton wool, obtained as in experiment *d.* Repeat this, after exposing the infected wool to the vapour of various antiseptics (43. 57. *b.*)

j. Try if the infection is produced through the stomach by adding to the food infected liquids.

k. Try if the infectious matter is on the skin, by washing a portion of it, and inoculating a healthy beast with the liquid.

l. Condense the volatile matter of the fæces of diseased animals, and try if the infection is present in it.

m. Examine the gas which collects under the skin in cases of emphysema, chemically, microscopically, and in relation to its power of communicating infection.

n. Continue the experiments on injecting antiseptics into the blood of diseased animals (77. to 96.). In this manner, try the action of sulphites, bisulphites, hypophosphites, and the substances mentioned in experiment *a.* The injections can be repeated several times on the same animal, by tying in the vein a tube furnished with a stop-cock.

o. Repeat, several times, the experiment of placing together in the same shed a healthy and a plague-stricken animal, and endeavour by any method which promises best to save the diseased animal from death, and avert the pestilence from the healthy one. Previous experiments (56. 65.) show that the favourable solution of this problem is far from unlikely.

p. Try the preventive and curative effect, once or oftener in twenty-four hours, of submitting the animal for a certain time in a small chamber filled with strong disinfecting or antiseptic vapour, so that the whole

current of the blood and substance of the tissues may be speedily and strongly impregnated with it (46.).

q. Repeat some or all of the foregoing experiments on sheep; and try any fresh experiments which may be suggested in the course of the inquiry.

Experiments *g*, *h*, and *i* will show beyond a doubt whether the virus of cattle plague is destroyed by carbolic acid. Valuable information would be gained by occasionally pushing the experiments *n* and *p* to a fatal issue. It is probable that the carcase of a diseased beast, killed by either of these experiments, will be found to be efficiently disinfected; and should this prove to be the case, the administration of a fatal dose of disinfectant will usefully replace the poleaxe.

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99. In dealing with the cattle plague it is possible to try testing experiments of a nature wholly inadmissible where human beings are concerned; and thus it is feasible to suppose that from the lessons derived from this pestilence we might obtain insight into means of preventing, or even curing, zymotic diseases. Thus the theoretical views, the experiments, and results recorded in the preceding pages, possess an interest beyond the immediate sphere of cattle plague. They point forcibly to the possible prevention and cure of all zymotic diseases which attack the human race, and thus possess a far wider and more momentous significance than if they related only to cattle. Every argument brought forward, every experiment detailed, and every result obtained in the course of this investigation, apply with overwhelming force to such visitations as typhus and typhoid fever, small-pox, diphtheria, and to that terrible scourge which for some time past has been threatening our shores.

100. The free use of the disinfecting agents here pointed out might not only save the country from the ravages of this pestilence, but it would ameliorate the physical condition of the people. Although foul sewage and putrefying animal matter are probably insufficient to generate the first septic germ of zymotic

disease, there can be no question that when such diseases do attack a population they spread with the greatest virulence wherever such putrescent materials abound. Highly important results might be expected to follow the general use of antiseptics, whether applied to farm buildings, where large quantities of manure are produced, or to sewage, whatever its destination,—whether allowed to fester in cesspools, pollute our rivers, or return to the soil. In tracts of land to which sewage, disinfected with carbolic acid, has been applied, the sheep are free from foot-rot, the potatoes from disease. Obnoxious insects, such as turnip-fly, gnats, and dung-flies, are absent; and grubs, larvæ, and the lower forms of animal life, and infusoria (the invariable accompaniments of putrefying matter) disappear; whilst vegetation becomes remarkably healthy and luxuriant. It is also highly probable that those imperceptible, but injurious emanations from the soil, known as malaria, would be destroyed, for Dr. Angus Smith* has conclusively proved that the putrefactive decomposition in soils, which produces malaria, does not take place in presence of very minute quantities of carbolic acid; and Dr. M'Culloch has shown that the unhealthiness of many parts of England may be traced to such exhalations. It therefore may be expected that, by extending the sphere of operation of these preventive appliances, we may not only diminish the loss of much valuable property and much sustenance of the people, but even diminish the risk and extend the term of the natural life of man.

April 25, 1866. WILLIAM CROOKES.

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* "On the Production and Prevention of Malaria." By Dr. R. Angus Smith, F.R.S.—Memoirs of the Literary and Philosophical Society of Manchester, vol. i., 1861.

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